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Title: Criticality Acccident Alarm System (CAAS) CSG-UM Hybrid Example

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Criticality Accident Alarm System (CAAS)
CSG-UM Hybrid Example

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CAAS Example

Criticality Accident Alarm System calculations combine methods needed for both criticality and shielding calculations. UM may be used for facility details, allowing import of existing facility drawing. CSG used for criticality cells.

Objectives:

- Demonstrate a hybrid method using unstructured mesh for facility and CSG for criticality cells
- Import solid geometry, generate mesh, create calculation in Attila4MC and pack for MCNP
- Generate a source file from KCODE calculation in MCNP
- Define tallies to calculate energy deposition to a detector
- Employ variance reduction techniques to obtain statistically significant results

CAAS Example

Steps in Hybrid Method:

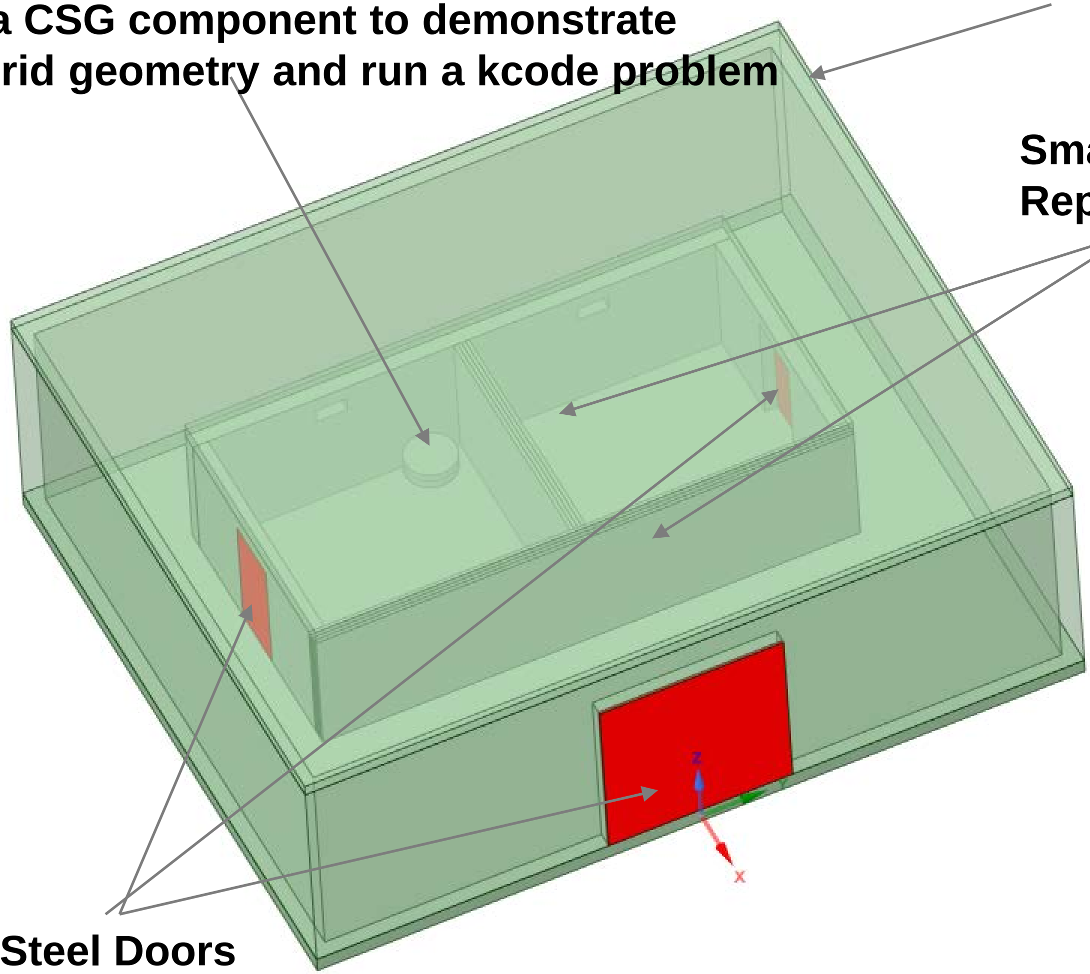
- Solid geometry import into Attila4MC
- Generate Mesh in Attila4MC
- Create calculation in Attila4MC and pack for MCNP
- Modify MCNP6.2 input file for insertion of CSG cells
- Run MCNP6.2 KCODE calculation with SSW
- Run MCNP6.2 fixed source calculation with SSR
- Variance Reduction steps to obtain detector result

CAAS Example

Critical Assembly to be modeled
As a CSG component to demonstrate
Hybrid geometry and run a kcode problem

Concrete Walls and Roof

Small Poly Spheres
Representing Detectors



Steel Doors

CAAS Example

Steps in Hybrid Method:

- **Solid geometry import into Attila4MC**
- Generate Mesh in Attila4MC
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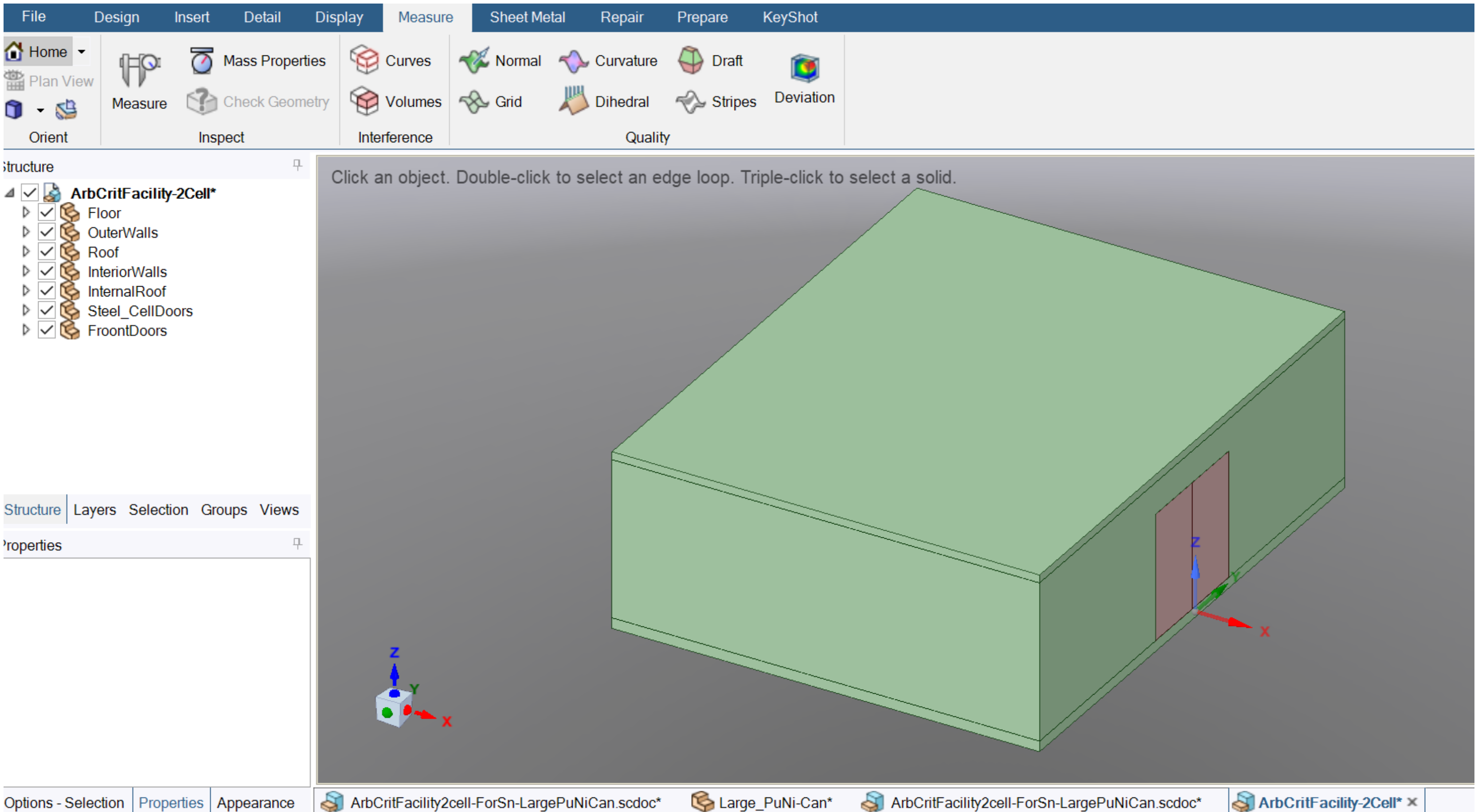
CAAS Example

Solid geometry import into Attila4MC

ArbCritFacility-2Cell.x_t -- view parasolid file in Spaceclaim → import into Attila4MC



CAAS Example

Steps in Hybrid Method:

- Solid geometry import into Attila4MC
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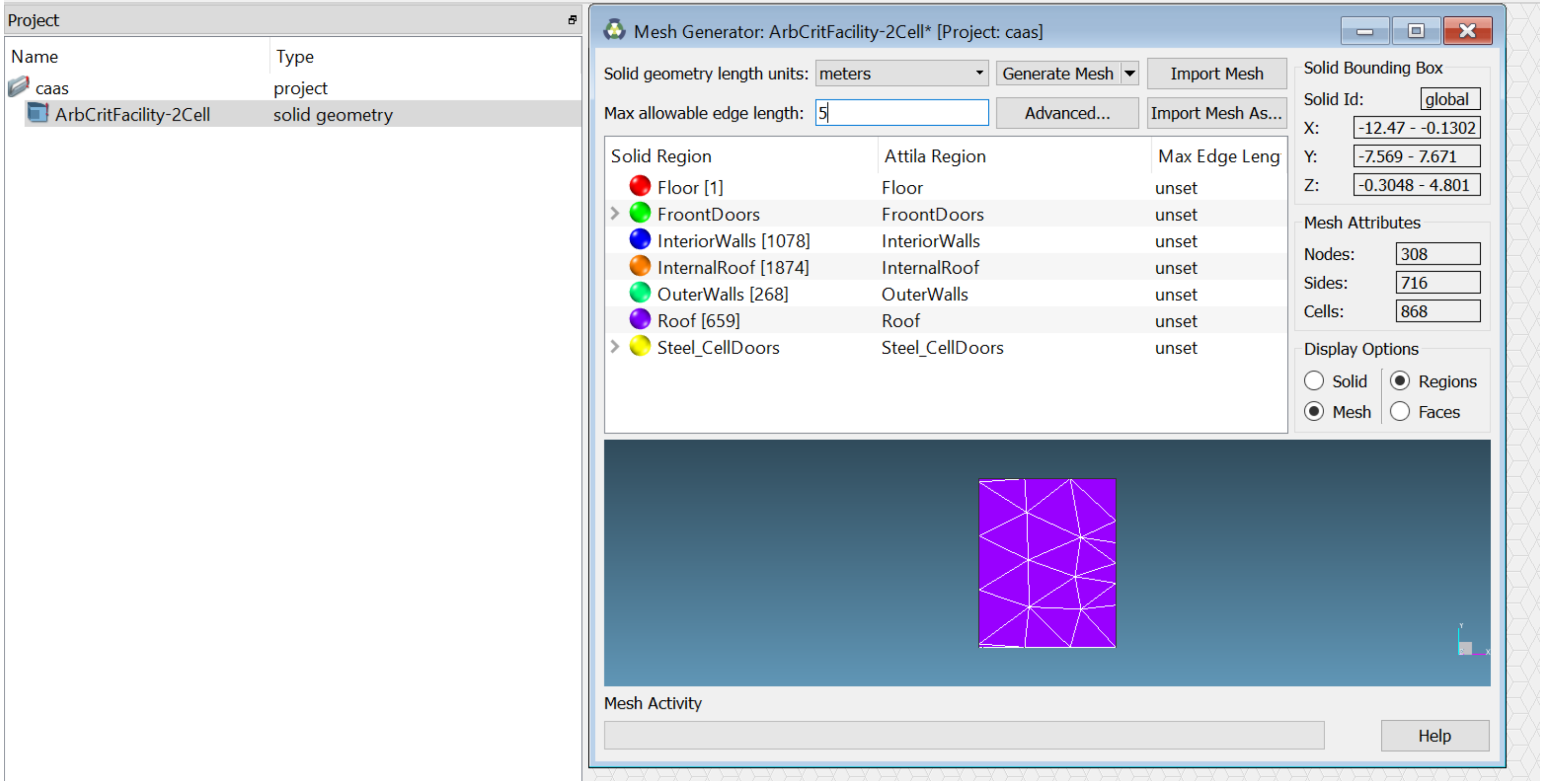
CAAS Example

Generate Mesh in Attila4MC:

File: New: Project: caas
Project: Import file: Solid Geometry: **ArbCritFacility-2Cell.x_t**
Generate Mesh (unclick Identify Empty Regions) → **ArbCritFacility-2cell.mesh.inp**



CAAS Example

Steps in Hybrid Method:

- Solid geometry import into Attila4MC
- Generate Mesh in Attila4MC
- **Create calculation in Attila4MC and pack for MCNP**
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CAAS Example

Create calculation in Attila4MC and pack for MCNP

Project: Create Object > Calculation

Library Name: **MCNP_Isotopes_Lib.xs.aux.inp** (must have cross sections imported)

Material – choose material for each Attila region

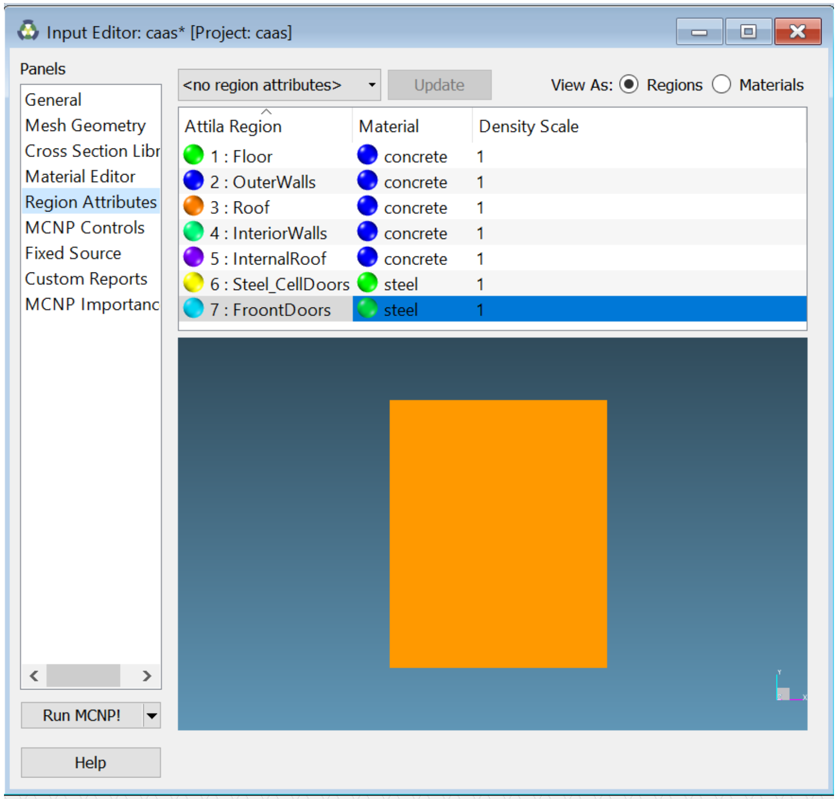
To import materials – Project: Import MCNP Attribues…**arb_crit_facility-CSG.mcnp**.i

Use panels to specify

Calculation> Pack for MCNP

arbcritfacility-2cell.mcnp.i

arbcritfacility-2cell.abaq



CAAS Example

Steps in Hybrid Method:

- Solid geometry import into Attila4MC
- Generate Mesh in Attila4MC
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- Variance Reduction steps to obtain detector result

CAAS Example

Modify MCNP6.2 input file for insertion of CSG cells

```
Caas Hybrid CSG-UM
c
c Attila calculation "MCNP_Materials"
c
c MCNP input file data converted to Attila atlp
c XML format by mcnp_convert, Varex.
c Source files:
c 1 "C:\Users\L121738\Desktop\arb_crit_facility-CSG.mcnp.i"
c
c -------------------------- Input Information ------------------------------ 80
c Attila GUI created MCNP6 Input
c Attila Version (not available)
c Input File Creation Date: Wed May 9 10:33:01 2018
c RxMesher version          : 1.0.0
c Simmetrix MeshSim version : MeshSim version 9.0
c Global mesh size          : 1 m
c Generated                 : 2018-04-25T18:14:06-06:00
c Solid Geometry :
c   Filename     : ArbCritFacility-2Cell.x_t
c   Last changed : 2018-04-25T18:11:47-06:00
c   MD5 checksum : d252c3276d70c263848a4710783acc40
c Note: RTT Mesh has added cell flags for MCNP Abaqus part and pseudo-cell.
c Associated Abaqus Unstructured Mesh :
c   Filename     : arbcritfacility-2cell.abaq
…
```

arbcritfacillity-2cell.abaq is the Abaqus file that must exist in the directory in this example

CAAS Example

Modify MCNP6.2 input file for insertion of CSG cells

```
c ----------------------------- Cell Cards ---------------------------------- 80
1     2    -2.3       0                  imp:n=1         u=1
2     2    -2.3       0                  imp:n=1         u=1
3     2    -2.3       0                  imp:n=1         u=1
4     2    -2.3       0                  imp:n=1         u=1
5     2    -2.3       0                  imp:n=1         u=1
6     1    0.08636      0                imp:n=1         u=1
7     1    0.08636      0                imp:n=1         u=1
8     0                 0                imp:n=1         u=1 $ background
9     0               -100 201 202 203  fill=1 imp:n=1 $ fill cell
c
c Criticality Cells CSG
21   0                -201 #30 #31 #32 #40  imp:n=1
22   0                -202 #41              imp:n=1
23   0                -203 #42              imp:n=1
c
c Pu Nitrate solution in cell 1
30    94 9.9270e-2      -301 -303      imp:n=1
31    0                 -301  303      imp:n=1
32    1     0.08636     -302  301      imp:n=1
c
c Detector Spheres
40    96  -0.92  -401  imp:n=1
41    96  -0.92  -402  imp:n=1
42    96  -0.92  -403  imp:n=1
c
c outside world
99    0                100 imp:n=0
```

CAAS Example

Modify MCNP6.2 input file for insertion of CSG cells

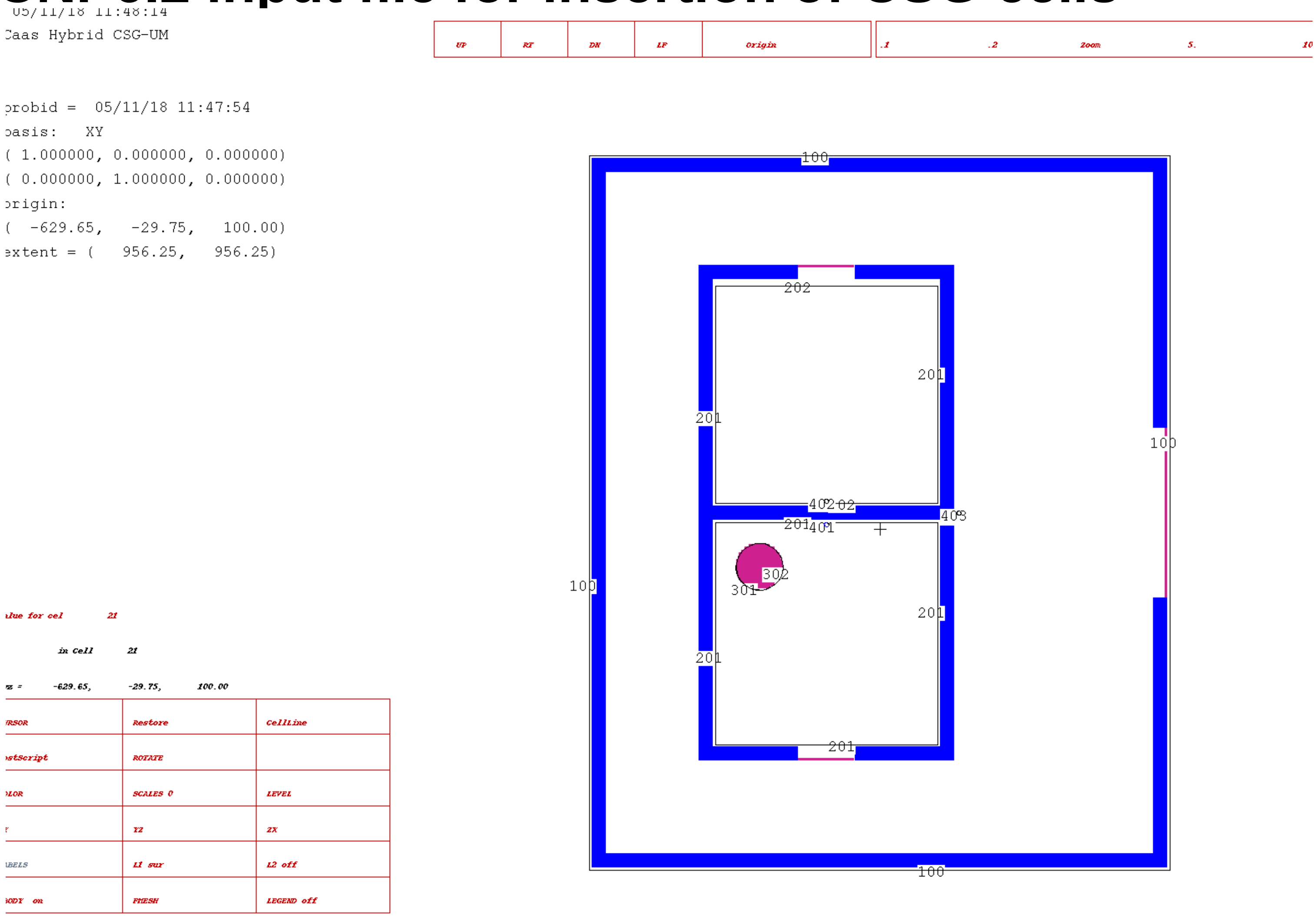
```
c ---------------------------- Surface Cards --------------------------------- 80
c
c 100 px -1252.46
c 101 px -8.0175
c 102 py -761.92
c 103 py 772.08
c 104 pz -35.48
c 105 pz 485.06
100 RPP -1252.46 -8.0175 -761.92 772.08 -35.48 485.06
c
c Crititicality Storage Cells with 5cm buffer to UM walls
201 RPP -983.38 -505.7  -492.83 -15.15  5.0 269.32
202 RPP -983.38 -505.7    25.15 492.83  5.0 269.32
203 SPH -460.2175 5.085 100 7
c
c Plutonium-Nitrate Container in inside corner of cell 1
301   RCC   -888.38 -110.15 100.0    0. 0. 131.7     50
302   RCC   -888.38 -110.15 99.0    0. 0. 132.7     50.5
303   pz    117.0
c
c Detector Sphere in inside corner of cell 2
401   sph -744.5375 -20.1549 100.0   5
402   sph -744.5375 30.3251  100.0   5
403   sph -460.2175 5.085      100.0   5
```

Modify MCNP6.2 input file for insertion of CSG cells

```
c PLUTONIUM-NITRATE SOLUTION
c    total number density = 9.9270e-2
c
m94   1001  6.0070e-2
       8016  3.6540e-2
       7014  2.3699e-3
      94239  2.7682e-4
      94240  1.2214e-5
      94241  8.3390e-7
      94242  4.5800e-8
mt94  lwtr            $ mt card invokes S(a,b) thermal scatter
c
c Polyethylene Detectors
m96 1001 2 6000 2
mt96 poly
```

CAAS Example

Modify MCNP6.2 input file for insertion of CSG cells



CAAS Example

Steps in Hybrid Method:

- Solid geometry import into Attila4MC
- Generate Mesh in Attila4MC
- Create calculation in Attila4MC and pack for MCNP
- Modify MCNP6.2 input file for insertion of CSG cells
- **MCNP6.2 KCODE calculation with SSW**
- MCNP6.2 fixed source calculation with SSR
- Variance Reduction steps to obtain detector result

Operated by Los Alamos National Security, LLC for the U.S. Department of Energy's NNSA

CAAS Example

- **MCNP6.2 KCODE calculation with SSW**
- **Generated with the SSW or "Surface Source Write" card.**
- **Form:** **SSW** **CEL = C1 C2 …**
  - The arguments after the CEL keyword is a list of cells to store fission source points for in a KCODE calculation.
  - Produces a file with default name wssa.
  - Additional options are available. See the MCNP Manual.

Surface Sources

- **MCNP can generate a binary file called a "surface source" file.**
  - Normally, this contains particle tracks that crossed a surface, which are run in a different calculation

- **The "surface source" file may also contain fission source points from a KCODE calculation.**

- **The surface source file may be used as the source from a criticality accident.**

- **Note: Surface sources do not yet work with OMP threading.**

Surface Source Considerations

- **Some considerations when deciding how many fission points to bank:**
  - Define NSS as the number of particles banked.
  - A sufficient number of fission source points is needed describe a continuous neutron field – more is usually better.
  - When reading the file, MCNP allows a variable number of particles NPS to be used.
  - If NPS < NSS, then NPS particles are randomly selected with an increased starting weight per history.
  - If NPS > NSS, then NSS starting particles are started, but some will be duplicated randomly with lower starting weight per history. Note that the NPS used for normalizing tallies is the same.

Generating a Surface Source

```
…
KCODE  20000  1.0   50  150
KSRC   -888.38    -110.15    108.5
ssw cel=30
…
```

- KCODE card to use 20,000 neutrons per cycle, initial guess for k-effective 1.0, skip 50 cycles, and run 100 active cycles
- Specify one source point in the center of the plutonium nitrate
- Add SSW card for cell 30.
- Run the problem, name the wssa file source.

```
mcnp6  i = caas1.txt  o = caas1o.txt wssa = source
```

- Note: This will generate 2 million source points and will take a long time.

- Examine results, verify run was successful and Shannon entropy check confirms source convergence

CAAS Example

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Surface Source Read

- **May read the surface source in a fixed source calculation.**
- **Form:** **SSR CEL = C1 C2 … WGT = W PSC = P**
  - The arguments after the CEL keyword is a list of cells to use from the surface source file.
  - W is the intensity of the source (neutrons released from the burst).
  - PSC is the probability of scattering cosine. From fission this is isotropic and 0.5. This is needed for F5 tallies and DXTRAN.
  - Reads a file with default name rssa.
  - Additional options are available. See the MCNP Manual.

Neutron Fission Treatment

- **Since fission was already treated in the KCODE calculation, it must be treated as capture.**

- **Form: NONU N1 N2 … N(NCEL)**

  - Specifies a list of cells where fission is treated as capture

    = 0, do not perform fission (treat as capture)

    = 1, perform fission
  - Must list “0” for each cell in the problem. May also do this on the cell card.
  - If this is not done, the problem will run forever because it is supercritical. Even if it were subcritical, the answer would be wrong.

Energy Deposition (F6) Tally

- **The neutron energy deposited in a cell may be obtained with an F6 tally.**

- **Form:** **F6:n C1 C2 …**

  - Computes energy deposition for each cell listed on the card in MeV/gram.
  - Otherwise, very much like an F4 tally, i.e., may use FM cards, etc.

Reading the Surface Source

- **Copy caas1.txt to caas2.txt.**
  - Modify the eeout file to meeout=caas2.mcnp.eeout
  - Delete the SSW card and insert a SSR card.
  - The intensity of the burst is 1e15 fissions times 2.9 neutrons per fission.
  - Delete KCODE and insert an NPS card with 1e5 neutrons.
  - Insert a NONU card and turn off fission in all cells.
  - Create an energy deposition tally for cell 40. Convert the units of the tally to Gy or J/kg (1.602e-10 is the conversion factor from MeV/gram to J/kg).
  - Run the problem reading the file source.

```
mcnp6  i = caas3.txt  o = caas3o.txt  rssa = source
```

  - Analyze the tally output.

Caas2.txt

Caas1.txt

```
. . . . .
kcode  20000   1.0   50  150
KSRC   -888.38 -110.15 108.5
ssw cel=30
. . . . .
```

Caas2.txt

```
. . . . . .
c Source Definition
ssr cel=30 wgt=2.9e15 psc=0.5
nonu 0 18r
c
c Histories (or Computer Time Cutoff)
nps 1e6
c
c Tallies or embee cards
fmesh4:n ORIGIN=-1255. -750. 0.
        IMESH=0.  IINTS=184
        JMESH=750.  JINTS=124
        KMESH=450.  KINTS=36
c
f16:n 40
fm16 1.6022e-10
fc16 Criticality Accident Dose at Detector 1 in Gy
```

Caas2.txt

Caas2.txt

Examine Results

```
========================================================================================
===================================

   results of 10 statistical checks for the estimated answer for the tally fluctuation chart (tfc) bin of tally    16

tfc bin    --mean--     ---------relative error---------     ----variance of the variance----     --figure of merit--     -pdf-
behavior   behavior     value   decrease   decrease rate     value   decrease   decrease rate     value    behavior     slope

desired    random    <0.10    yes    1/sqrt(nps)    <0.10    yes    1/nps      constant   random    >3.00
observed    random    0.14    yes    yes    0.05    yes    yes    constant    random    10.00
passed?    yes    no    yes    yes    yes    yes    yes    yes    yes    yes

========================================================================================
===================================

16   missed  1 of 10 tfc bin checks: the relative error exceeds the recommended value of 0.1 for nonpoint detector tallies
     missed all bin error check:    1 tally bins had    0 bins with zeros and    1 bins with relative errors exceeding 0.10
```

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- **Variance Reduction steps to obtain detector result**

CAAS Example

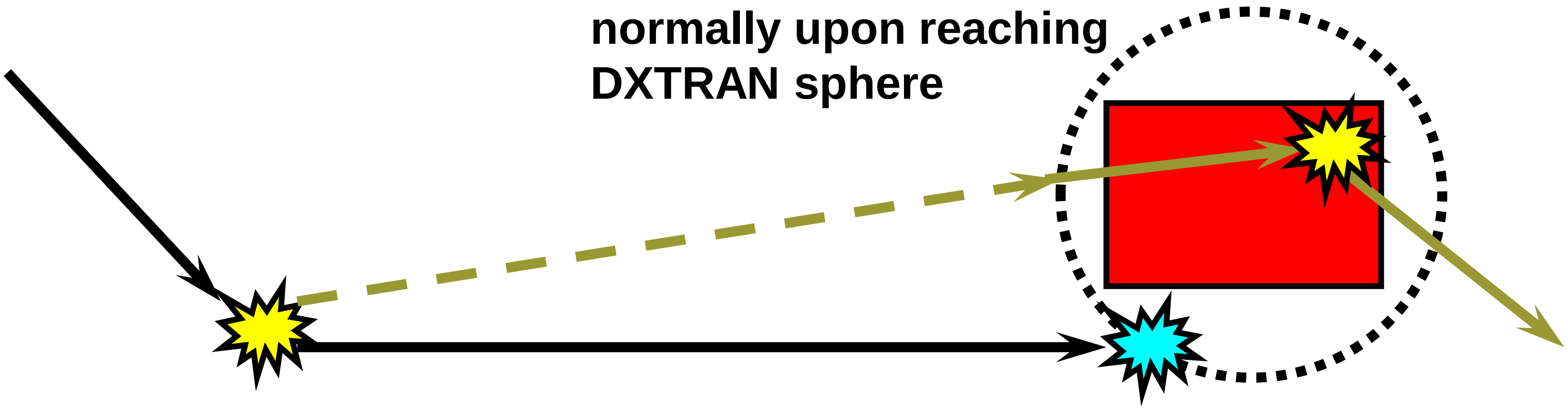
Variance Reduction steps to obtain detector result

- **MCNP offers several variance reduction techniques:**
  - Implicit capture
  - Splitting
  - Russian Roulette
  - Weight Cutoff (Roulette)
  - **DXTRAN Spheres**
  - **Energy Splitting**
  - **Forced Collisions**
  - Weight Windows
  - Source Biasing
  - Exponential Transform
- **We will discuss some of these at a basic level**
  - Take our advanced variance reduction class for a more complete overview
  - Importances, weight windows and CADIS discussed earlier in class
  - CAAS example for CSG-only presented in Criticality class

CAAS Example

DXTRAN Spheres

- **Unfortunately, the most useful VR technique for this problem is the most difficult to understand.**
- **Scattering to a specific region may be improved with angular biasing created with DXTRAN spheres.**



Pseudoparticle transports normally upon reaching DXTRAN sphere

At each collision, transport pseudoparticle to DXTRAN sphere

Real particle terminates if it reaches the sphere

CAAS Example

DXTRAN Spheres

- **DXTRAN spheres cover a region of space. Particles are “pulled” to that region each collision.**

- **Form:** **DXT:n X0 Y0 Z0 Rin Rout WC1 WC2**

  - First three entries are the coordinates for the center of the DXTRAN sphere.
  - Rin and Rout are the inner and outer radii of the sphere to refine angular biasing. Usually Rin = Rout.
  - WC1 and WC2 are weight cutoff parameters to roulette low weight particles. Important especially if multiple DXTRAN spheres are present.

CAAS Example

DXTRAN Spheres

- **Copy caas2.txt to caas3.txt.**
  - Place a DXTRAN sphere covering the detector cell. Use identically inner and outer radii. WC1 = 5e-6 and WC2 = 1e-6 to cull low-weight particles.
  - Run the problem:

```
mcnp6  i = caas3.txt  o = caas3o.txt  rssa = source
```

Analyze the tally results.

```
1tally     16      nps =     2003539
+                               Criticality Accident Dose at Detector 1 in Gy
         tally type 6    track length estimate of heating.
         particle(s): neutrons
 number of histories used for normalizing tallies =      2003539.00
         this tally is all multiplied by  1.60220E-10
         masses
                cell:      40
                     4.81711E+02
 cell  40
              2.68033E-02 0.0077
```

CAAS Example

DXTRAN Spheres

Caas2.txt

```
. . . . .
c Source Definition
ssr cel=30 wgt=2.9e15 psc=0.5
nonu 0 18r
c
c Histories (or Computer Time Cutoff)
nps 1e6
c
c Tallies or embee cards
fmesh4:n ORIGIN=-1255. -750. 0.
        IMESH=0.  IINTS=184
        JMESH=750.  JINTS=124
        KMESH=450.  KINTS=36
c
f16:n 40
fm16 1.6022e-10
fc16 Criticality Accident Dose at Detector 1 in Gy
```

Caas3.txt

```
. . . . .
c Source Definition
ssr cel=30 wgt=2.9e15 psc=0.5
nonu 0 18r
c
c Histories (or Computer Time Cutoff)
nps 1e6
c
c Tallies or embee cards
fmesh4:n ORIGIN=-1255. -750. 0.
        IMESH=0.  IINTS=184
        JMESH=750.  JINTS=124
        KMESH=450.  KINTS=36
c
f16:n 40
fm16 1.6022e-10
fc16 Criticality Accident Dose at Detector 1 in Gy
c
dxt:n -744.5375 -20.1549 100.0 5.0 5.0 5e-6 1e-6
```

CAAS Example

- **Energy splitting card:**

- **Form:** **ESPLT:n I1 E1 … IN EN**

  - First a list of importances where the default importance is 1.
  - If > 1, then neutrons are split when they enter energy region, if < 1, neutrons are rouletted.
  - List of energy bin bounds in descending order.

CAAS Example

- **Copy caas3.txt to caas4.txt.**

  - Introduce energy splitting at 1 keV and 1 eV.
  - Neutrons that downscatter below 1 keV should be rouletted 4 to 1 (I1 = 0.25)
  - Neutrons that downscatter below 1 eV should be rouletted 10 to 1 (I2 = 0.1).
  - Run the problem and analyze the results.

```
mcnp6  i = caas4.txt  o = caas4o.txt  rssa = source
```

  - Problem should run faster, but variance should be higher. This is okay because less time is spent tracking unimportant particles.

CAAS Example

- **Energy Splitting**

Caas3.txt

```
. . . . .
c Source Definition
ssr cel=30 wgt=2.9e15 psc=0.5
nonu 0 18r
c
c Histories (or Computer Time Cutoff)
nps 1e6
c
c Tallies or embee cards
fmesh4:n ORIGIN=-1255. -750. 0.
        IMESH=0.  IINTS=184
        JMESH=750.  JINTS=124
        KMESH=450.  KINTS=36
c
f16:n 40
fm16 1.6022e-10
fc16 Criticality Accident Dose at Detector 1 in Gy
c
dxt:n -744.5375 -20.1549 100.0 5.0 5.0 5e-6 1e-6
```

Caas4.txt

```
. . . . .
c Source Definition
ssr cel=30 wgt=2.9e15 psc=0.5
nonu 0 18r
c
c Histories (or Computer Time Cutoff)
nps 1e6
c
c Tallies or embee cards
fmesh4:n ORIGIN=-1255. -750. 0.
        IMESH=0.  IINTS=184
        JMESH=750.  JINTS=124
        KMESH=450.  KINTS=36
c
f16:n 40
fm16 1.6022e-10
fc16 Criticality Accident Dose at Detector 1 in Gy
c
dxt:n -744.5375 -20.1549 100.0 5.0 5.0 5e-6 1e-6
esplt:n 0.25 1e-3 0.1 1e-6
```

CAAS Example

Forced Collisions

- **Indicates that rare collisions with air in the room contribute most to the tally.**
- **Want to sample collisions more often, but at a lower weight.**
- **MCNP can do this with forced collisions.**
  - Forced collisions decompose the particle into a collided and uncollided part.
  - The collided part plays the DXTRAN game and can contribute to the tally.
  - This is done on a per cell basis only (for now).
- **Forced Collision Card:**
- **Form:** **FCL:n F1 F2 ... F(ncel)**
  - List of forced collision parameters Fi from 0 to 1, which is the probability of playing the forced collision game.
  - May also specify each one individually on the cell card.